Bristol air pollution: How does it vary with time of day and temperature?

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1. Introduction

We aimed to investigate the diurnal pattern of air pollution in Bristol and whether (because of pollution from heating) this varies according to the ambient temperature. We did this by analysing historical records of PM2.5 air pollution from the DEFRA monitoring station at St Pauls and records of temperature from Bristol airport.

2. Methods

We analysed PM2.5 because it is one of the most harmful pollutants and one of the few pollutants measured by official (DEFRA) monitors. We chose the DEFRA monitor at St Pauls, Bristol because it is one of the few official monitors in SW England and one of very few "background" (as opposed to "roadside") monitors, meaning that it is not dominated by traffic pollution. Each PM2.5 observation is reported in units of µg/m^3, to one decimal place until June 2019 but as an integer since June 2019.

We used temperature data from Bristol airport because it is the closest official source of weather data to Bristol. Unfortunately the elevation of this site is 190 m, so the temperature is likely to be lower than that at the DEFRA monitor (elevation 15 m). Each temperature observation is reported as an integer number of °C.

Data for both PM2.5 concentration and temperature are recorded hourly. We used all hourly observations of PM2.5 concentration but only one temperature observation for each day, specifically the midnight UTC one. The midnight temperature observation was expected to reflect the need for heating during the corresponding evening.

For analysis purposes, we defined each day to begin at 12:00 UTC to avoid the more highly polluted evening/night period being split between successive days. For each day we obtained 24 observations of PM2.5 concentration (12:00, 13:00, …, 11:00 UTC) and one observation of temperature (0:00 UTC).

We obtained data covering the 10-year period beginning 2013-02-12 at 12:00, which was the most recent 10-year period at the time of the research. The use of a 10-year period was a compromise: a longer period would be desirable to include a wide range of temperatures, whereas a shorter period would be preferable for reflecting current pollution patterns.

The 10-year period contained 3652 days but some of them (749 days) were excluded:

1. December 31 each year.
2. November 5 each year.
3. If November 5 was a Friday, the following days were also excluded: the next day, the preceding Friday and Saturday, and the following Friday and Saturday (i.e., October 30 and 31 and November 6, 12, and 13).

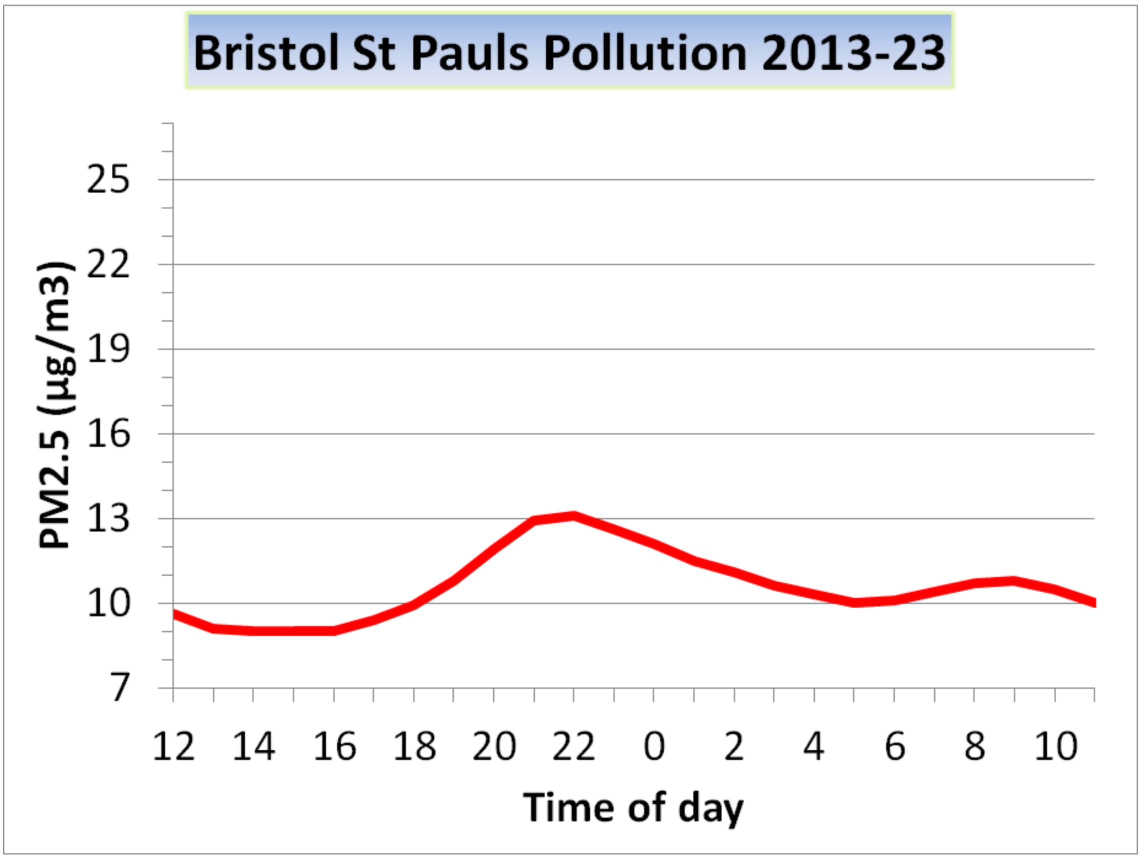
4. If November 5 was a Saturday, the following days were also excluded: the previous day, the preceding Friday and Saturday, and the following Friday and Saturday (i.e., October 29 and 30 and November 4, 11, and 12).
5. If November 5 was neither a Friday nor a Saturday, the preceding Friday and Saturday and the following Friday and Saturday were also excluded.
6. Days on which the midnight temperature observation was missing.
7. Days on which any of the 24 pollution observations was missing.
8. Days on which the midnight temperature was less than −5°C.
9. Days on which the midnight temperature was greater than 23°C.

The reason for (1–5) above is to exclude days when firework pollution is likely. The reason for (8–9) is to ensure a reasonable number of days with each temperature value; midnight temperatures at Bristol airport are rarely less than −5°C or greater than 23°C.

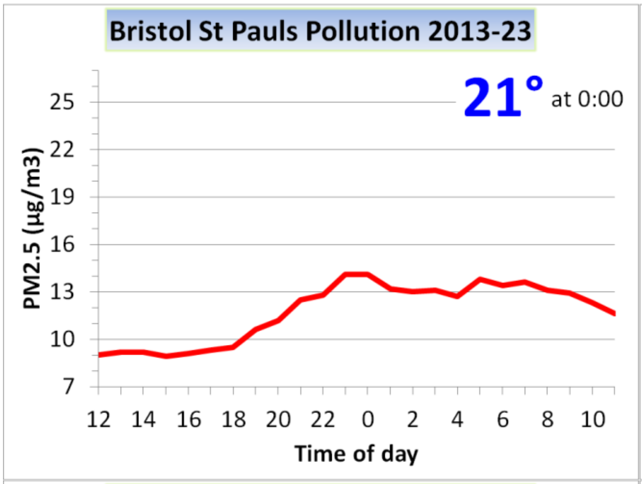
We analysed the data by simply obtaining the sets of days with each midnight temperature, ranging from −3°C to 21°C. To increase the number of days with each temperature value, we expanded each set to include midnight temperatures of 1°C or 2°C above or below the target temperature. For example, the −3°C set comprised all days with a midnight temperature in the range [−5°C, −1°C] and the −2°C set comprised all days with a midnight temperature in the range [−4°C, 0°C]. For each such set of days, the mean PM2.5 concentration was calculated for each of the 24 hours.

3. Results

The PM2.5 concentration for each of the 24 hours, averaged over all 2903 days, is plotted below.



The following plots average the PM2.5 concentration over the days corresponding to each of the temperatures between −3°C and 21°C.


Bristol St Pauls Pollution 2013-23
21° at 0:00
PM2.5 (µg/m3)
25
22
19
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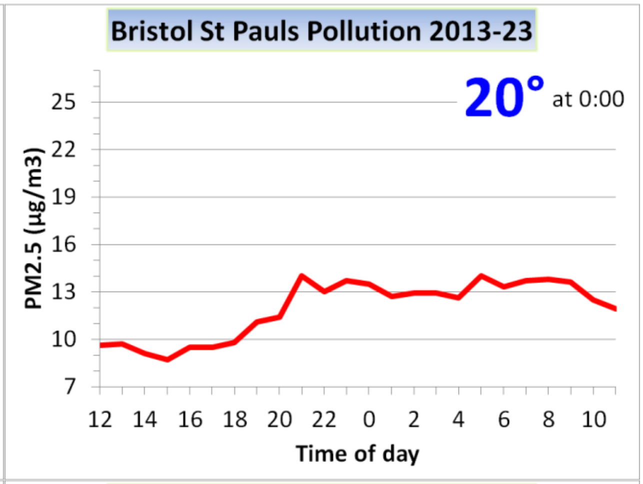
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
20° at 0:00
PM2.5 (µg/m3)
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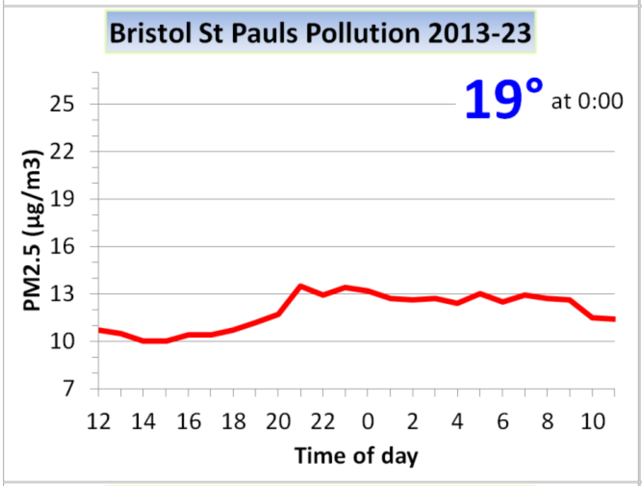
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
19° at 0:00
PM2.5 (µg/m3)
25
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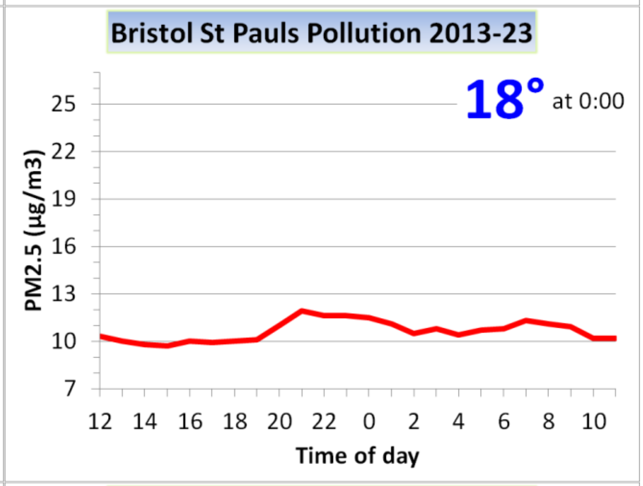
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
18° at 0:00
PM2.5 (µg/m3)
25
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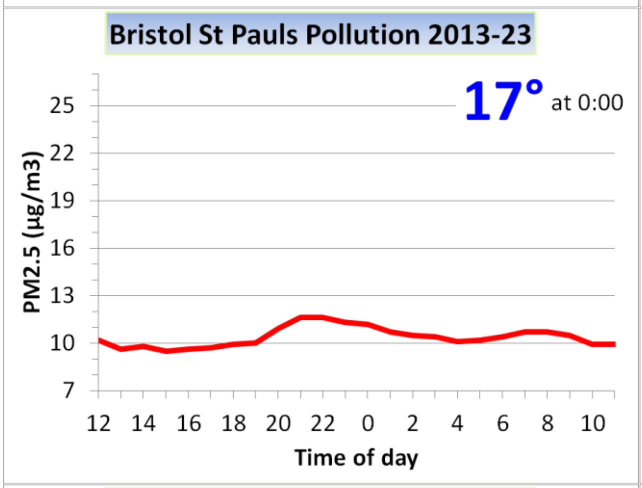
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
17° at 0:00
PM2.5 (µg/m3)
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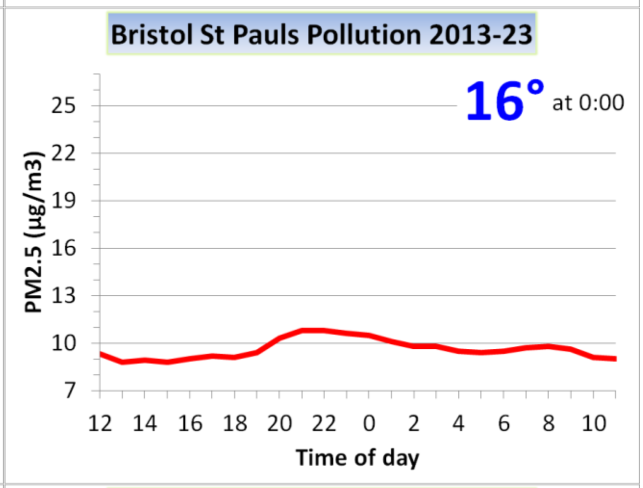
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
16° at 0:00
PM2.5 (µg/m3)
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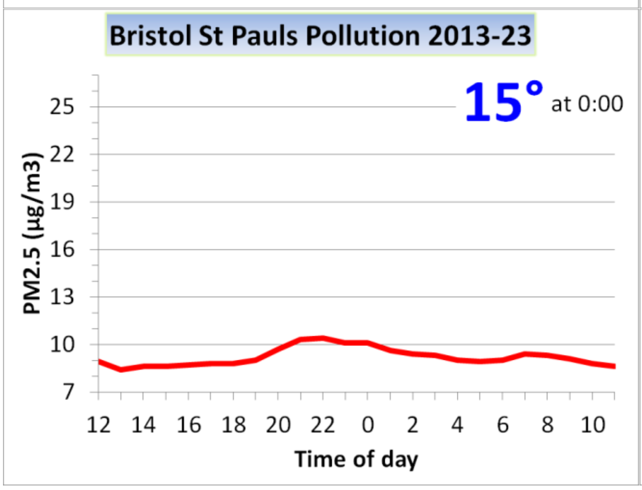
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
15° at 0:00
PM2.5 (µg/m3)
25
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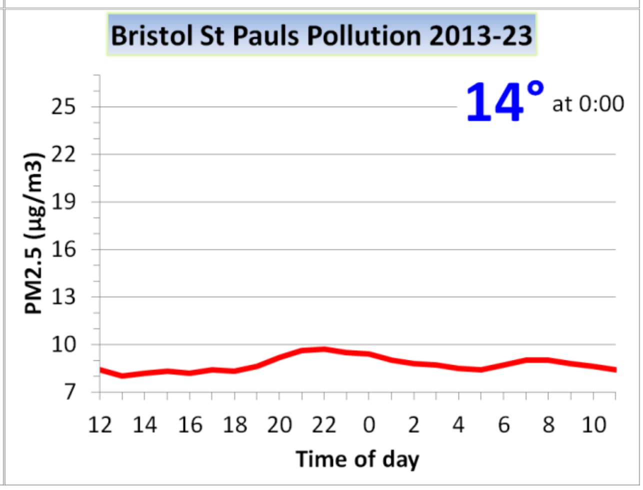
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
14° at 0:00
PM2.5 (µg/m3)
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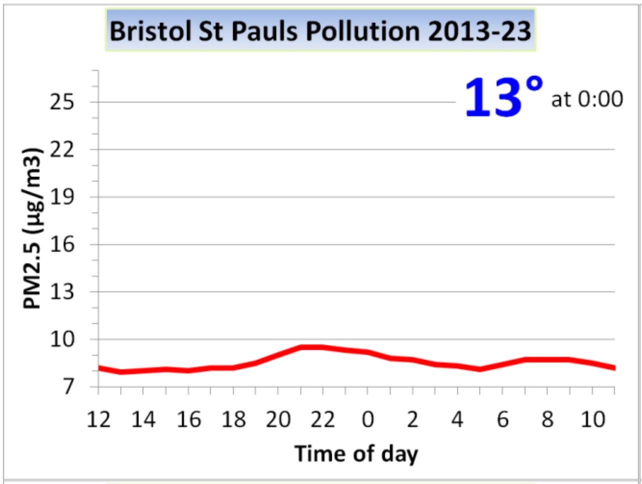
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
13° at 0:00
PM2.5 (µg/m3)
25
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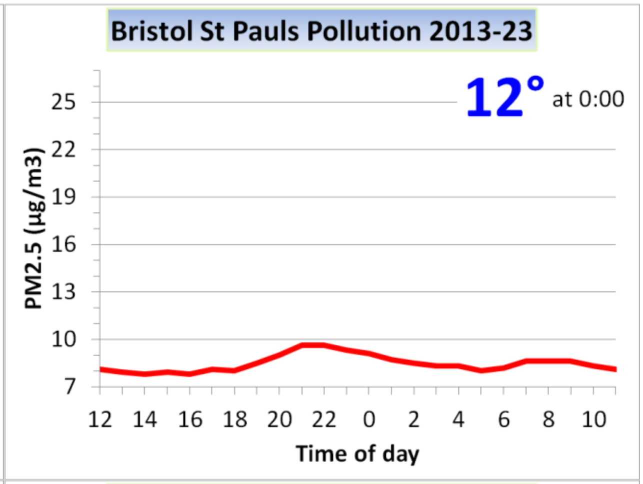
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
12° at 0:00
PM2.5 (µg/m3)
25
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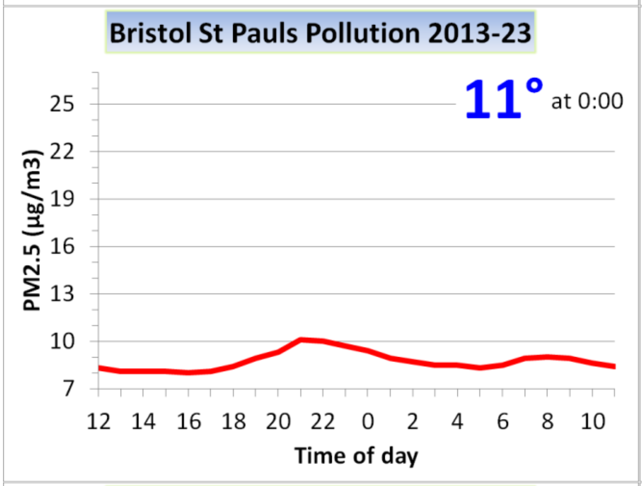
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
11° at 0:00
PM2.5 (µg/m3)
25
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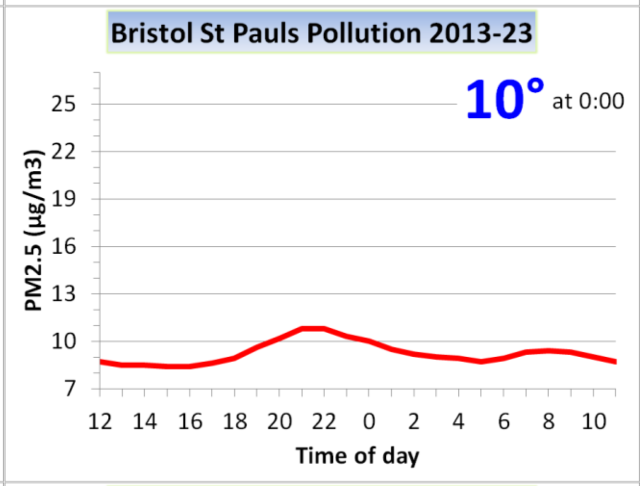
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
10° at 0:00
PM2.5 (µg/m3)
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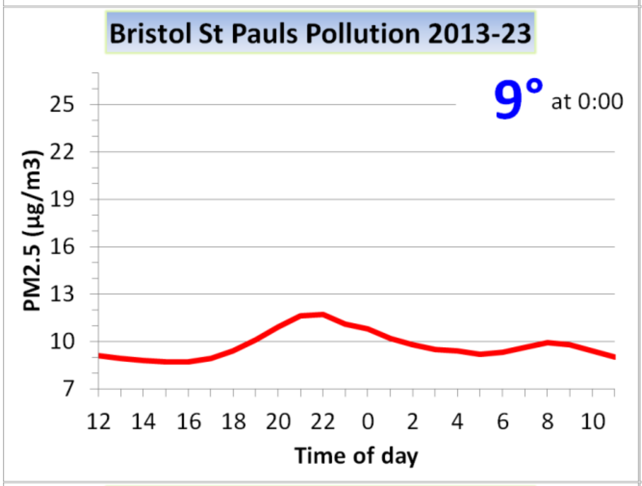
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
9° at 0:00
PM2.5 (µg/m3)
25
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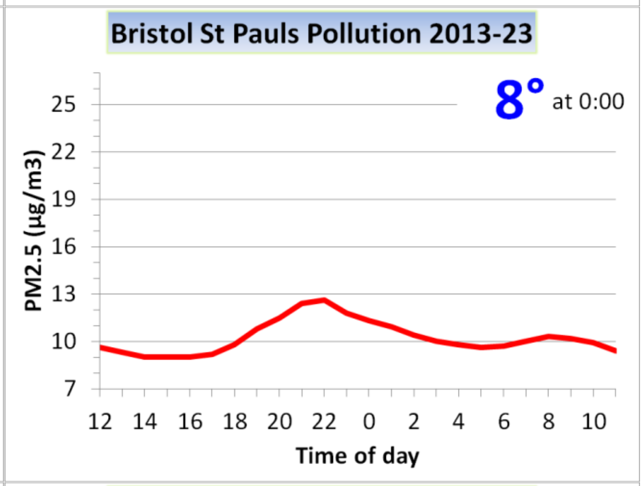
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
8° at 0:00
PM2.5 (µg/m3)
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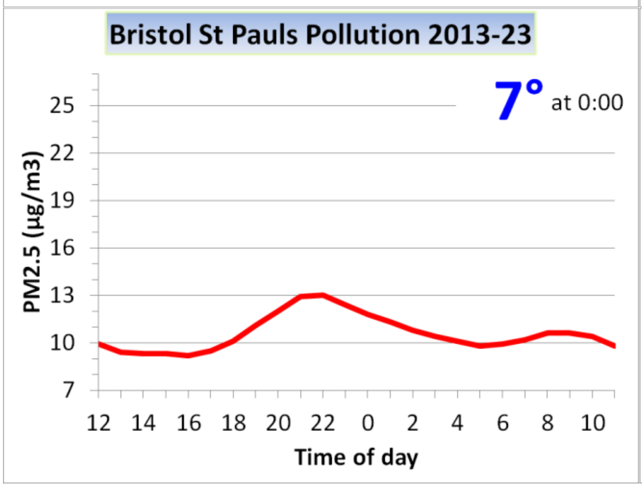
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
7° at 0:00
PM2.5 (µg/m3)
25
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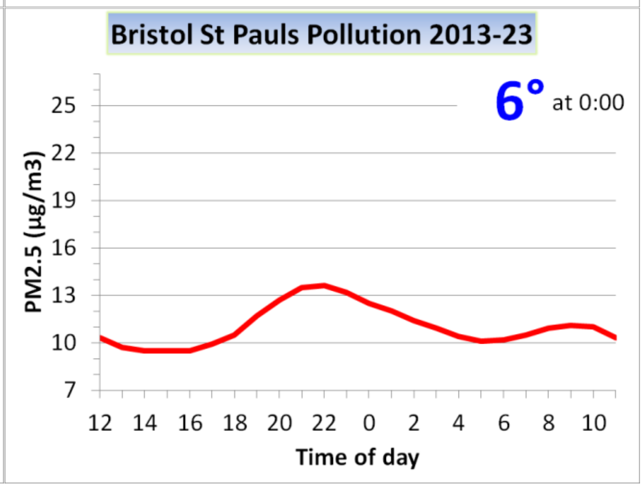
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
6° at 0:00
PM2.5 (µg/m3)
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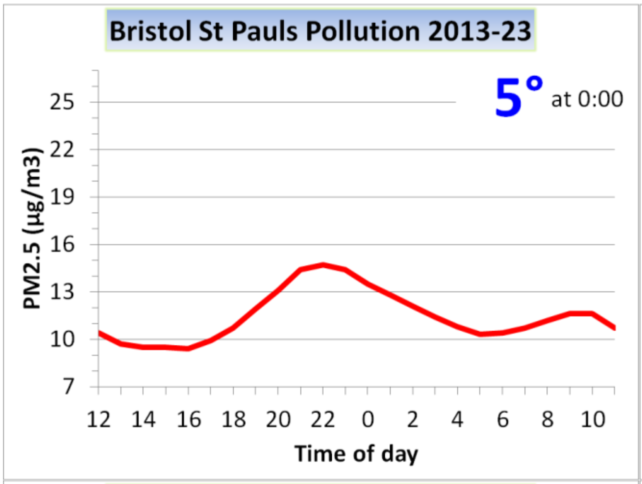
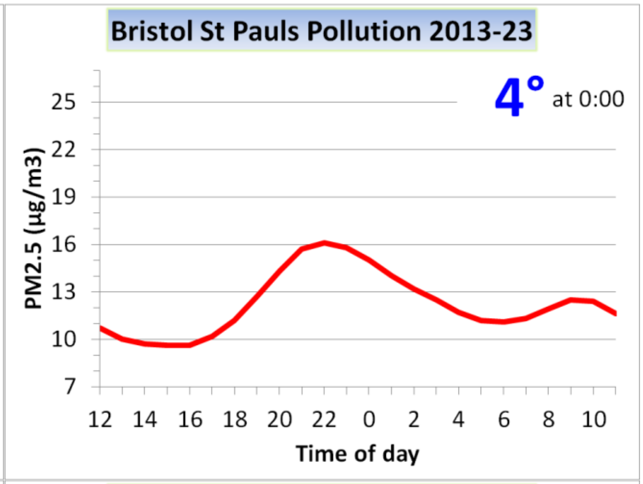
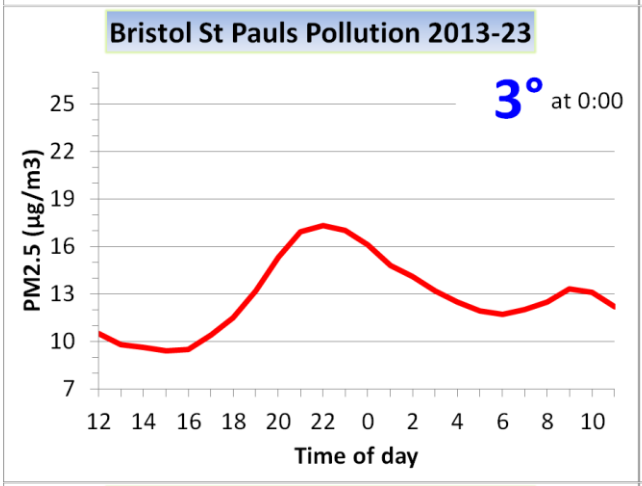
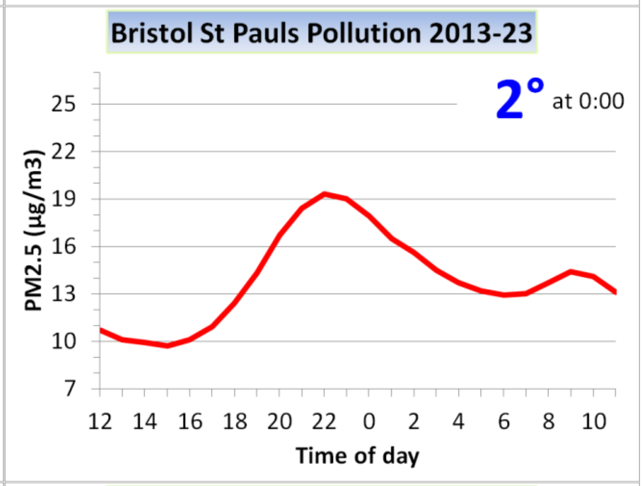
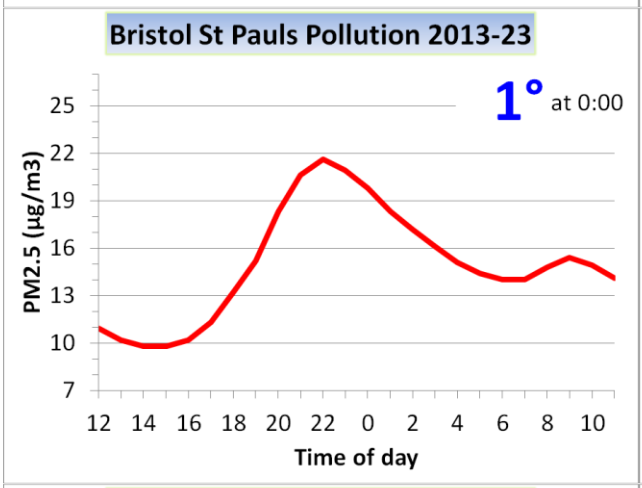
12 14 16 18 20 22 0 2 4 6 8 10
Time of day

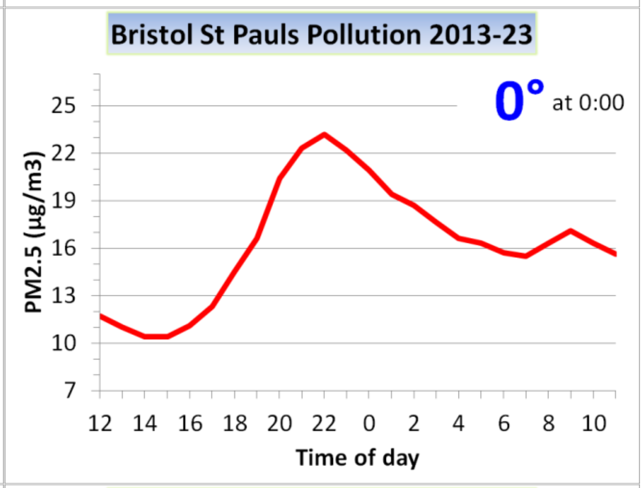

Bristol St Pauls Pollution 2013-23
5° at 0:00
PM2.5 (µg/m3)
25 22 19 16 13 10 7
12 14 16 18 20 22 0 2 4 6 8 10
Time of day

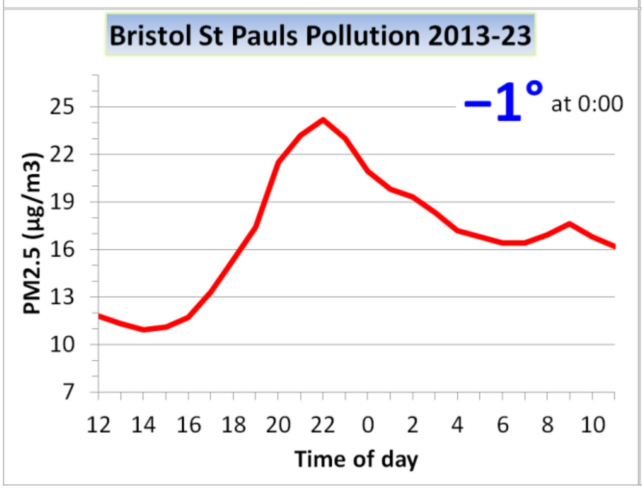

Bristol St Pauls Pollution 2013-23
4° at 0:00
PM2.5 (µg/m3)
25 22 19 16 13 10 7
12 14 16 18 20 22 0 2 4 6 8 10
Time of day

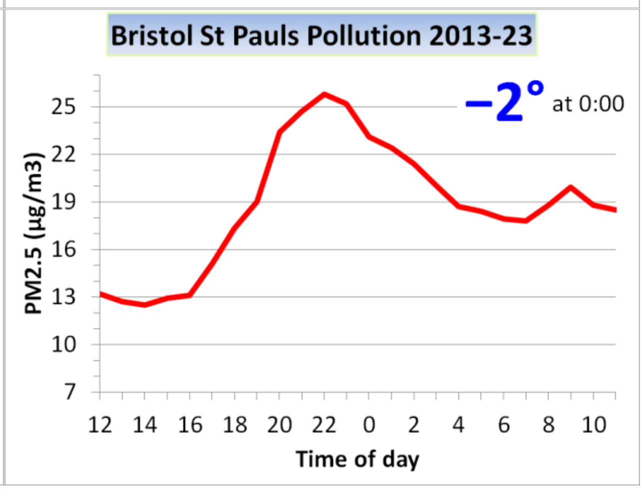

Bristol St Pauls Pollution 2013-23
3° at 0:00
PM2.5 (µg/m3)
25 22 19 16 13 10 7
12 14 16 18 20 22 0 2 4 6 8 10
Time of day

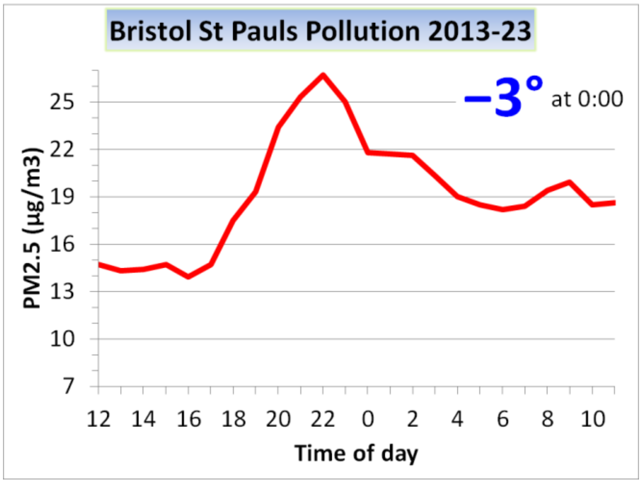

Bristol St Pauls Pollution 2013-23
2° at 0:00
PM2.5 (µg/m3)
25 22 19 16 13 10 7
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
1° at 0:00
PM2.5 (µg/m3)
25 22 19 16 13 10 7
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
0° at 0:00
PM2.5 (µg/m3)
25 22 19 16 13 10 7
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
−1° at 0:00
PM2.5 (µg/m3)
25 22 19 16 13 10 7
12 14 16 18 20 22 0 2 4 6 8 10
Time of day


Bristol St Pauls Pollution 2013-23
−2° at 0:00
PM2.5 (µg/m3)
25 22 19 16 13 10 7
12 14 16 18 20 22 0 2 4 6 8 10
Time of day



4. Discussion

Overall, the PM2.5 concentration peaks at 22:00, with a smaller peak at 9:00; the early afternoon is clearly the least polluted time of day. For most of the temperature range, as the midnight temperature decreases, pollution increases at all times of day but particularly around the 22:00 peak and, to a lesser extent, around the 9:00 peak. However, for midnight temperatures above 14°C, pollution instead *increases* gradually as the midnight temperature increases.

Both the 22:00 and 9:00 peaks appear to shift an hour earlier on warmer days (i.e., days with a higher midnight temperature), probably because warmer days tend to occur when daylight saving time is in force. This needs to be confirmed by analysing the data by time of year instead of midnight temperature. If confirmed, this would suggest that both peaks are due to human activity.

Our conjecture is that the 22:00 peak is caused by polluting forms of residential heating because it occurs throughout the evenings particularly in colder weather. Further research is needed to confirm this and to investigate the cause of the smaller peak at 9:00.

The reason for the increase in pollution with temperature on the warmest days is not yet clear. It may be caused by smoke from barbecues, which are more common at these temperatures. Alternatively, it may result from nonlocal phenomena that tend to accompany high midnight temperatures, such as light winds or the formation of smog from high ozone pollution. Again, further research is needed to find the reason.